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Software defined radio for ground and airborne GNSS reflectometry

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***Abstract*—Software defined radio (SDR) appears as a suitable solution for dedicated GNSS reflectometry (GNSS-R) applications. Not only does the flexibility of SDR allow for easy and rapid prototyping, but also do recent technological developments of SDR front-ends support real-time operation of GNSS-R. Our presentation includes a discussion about the technical aspects of SDR for GNSS-R and we show results from a ground-based GNSS-R SDR receiver which was operated continuously over a more than a month at the Onsala Space Observatory. A summary of our current activities in relation to airborne GNSS-R solutions and initial results in the form of Delay-Doppler Maps (DDMs) will conclude the presentation.**

Keywords—GNSS-R, software defined radio, signal processing, sea level, delay doppler maps

1. SDR for GNSS-R

Software-defined radio (SDR) is a very powerful and flexible concept for prototyping and quick realization of projects without the need of application-specific integrated circuit (ASIC) boards. Thus, SDR is a very appealing solution which helps to implement a novel GNSS-R concept with much lower prototyping and development cost. As signal processing can be carried out on the CPU, a GNSS-R solution can be built with off-the-shelf components and adapted in a very flexible way before or during any development phase. As discussed in the following, SDR has been also chosen for the development of a ground-based GNSS-R instrument which allows for correlation between the direct and reflected signals transmitted from the GLONASS constellation. SDR is also currently considered for the development of a light-weight GNSS-R Delay-Doppler Map (DDM) receiver which is expected to be operated from airborne platforms and balloons.

2. Realizing the "GLONASS-R" concept by means of SDR

The correlation of direct and reflected signals is not possible without certain hardware changes. However, in the case of Russian Global Navigation Satellite System (GLONASS) which makes use of the frequency division multiple access (FDMA) encoding scheme cm-level precision from ground-based GNSS-R installations can be obtained [1]. However, the need for complex. and expensive RF front-ends, down-conversion stages and A/D converters made the so-called GLONASS-R system rather unattractive for being duplicated at other sites. This problem was overcome by replacing those inflexible components with off-the-shelf software-defined radio equipment. This did not only lead to a drastic price reduction but also increases the flexibility of the GLONASS-R concept. Results from such a prototype system are documented in [2].

3. Preparations for a lightweight airborne receiver

Although the USRP N210 front-ends used for the ground-based solution discussed in Section 2 were sufficient to demonstrate the feasibility of the GLONASS-R concept and operate the system in real-time, their size and weight does not make them the optimal choice for a SDR based GNSS-R solution that can be mounted on an airborne platform with payload weight restrictions. Thus, another front-end solution was sought for and found in crowdfunding project LimeSDR shown in Figure 1.

Figure 1: The LimeSDR front-end, which has been chosen for this project, is based on field programmable RF transceiver technology, combined with FPGA and microcontroller chipsets.

This front-end offers a continuous frequency range between 100 kHz and 3.8 GHz, two RX channels with bandwidths of up to 61 MHz and an easy interface via the USB3.0. Moreover, the weight of about 60 g makes it an ideal candidate for the SDR front-end sought for our airborne GNSS-R system.

4. *Results from initial tests*

First tests in the GPS L1 band (see Figure 2) revealed that the obtained I/Q samples from the LimeSDR have enough dynamic resolution to deal with unwanted interference and the datalink via USB3.0 has been proven to sustain data rates corresponding to sampling rates of up to 10 Msps.

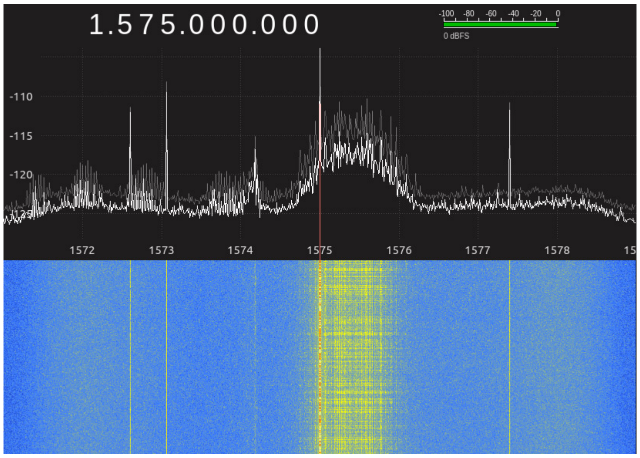

Figure 2: Screenshot of the GQRX SDR spectrum analyzer which was interfacing to the LimeSDR board. The GPS signal power at the L1 frequency is clearly received, while the board was tuned to a center frequency to 1575 with a sampling rate of 10 Msps.

5. *Outlook*

The software receiver for real-time computation of DDMs (Fig. 3) is currently under development and will be tested with the SDR front-end once all its functionalities have been validated. Initial tests will be performed at a location which oversees open water from a high vertical distance. Follow-on tests will then be carried out from an aerial platform.

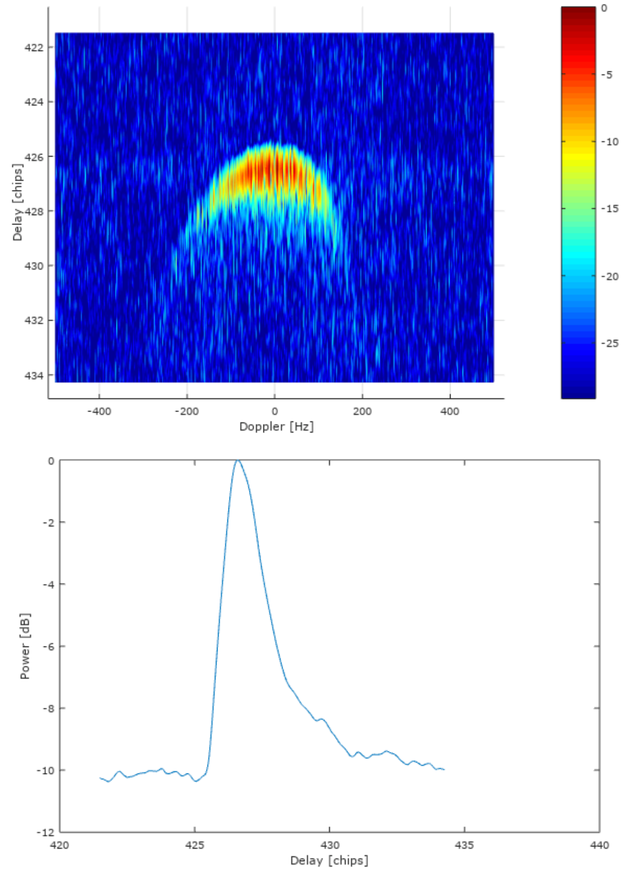

Figure 3: Example output of the software receiver. Results are based on recorded raw sampling data from an airborne GNSS-R experiment kindly provided from ICE-CSIC/IEEC, Spain. The upper plot depicts a DDM of a GPS satellite and the corresponding waveform is shown in the lower plot. The slope of the trailing relates to sea-surface roughness and can be used for wind-speed retrieval.

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